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ABSTRACT

This paper examines the concept of decalage from two cognitive-change positions (structures of logical thought and attentional and verbal mediators) and proposes an alternative explanation for decalage from a perceptual-change point of view. The term decalage is used to summarize the relation between differences in performance of various age groups and differences in information contained in problem-solving tasks that have the same solution requirements. According to the cognitive change position, age-related performance differences are assumed to result from different cognitive structures that evaluate the same information. However, this position cannot adequately explain decalage relations such as 8-year-olds conserving mass while 10-year-olds cannot conserve volume. In the perceptual-change position, decalage relations are assumed to be a source of information about developmental changes in the perceptual system and how that system determines what information is processed by cognitive structures. Two studies are described in which the dimensional salience of task components was manipulated in order to assess the role of perception in tasks usually used to measure cognitive change (matrix solution and relevant versus incidental recall). The results were interpreted as showing that perceptual salience was a significant determinant of the obtained decalages and it was suggested that perceptual characteristics could explain decalages found in other cognitive-change research. (JMB)

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The Decalage from the Perspective of a Perceptual Salience Account of Developmental Change

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Many years ago Piaget introduced the term "decalage" into the literature of developmental psychology. He used it to refer to the performance of children who had been given various types of conservation problems. Although the conservation decalage is well known, it has never been established in Piagetian theory why it should ever occur. Because conservation is presented as a reflection of a unitary construct comprised of logical operations that characterize the concrete operational stage, the failure of mass, weight, and volume conservation to appear simultaneously seems counter to what would be expected from the theory.

In one respect, the decalage could be viewed as a failure to replicate. Even though the solution requirements of various conservation problems were the same, successful performance varied as a function of the content or information specific to each task, and there is no internally consistent account for these performance differences in the theory. Therefore, decalage is not a theoretical construct and in no way provides an explanation for psychological development. It is rather a descriptive term which summarizes the relation between (a) differences in the performance of various age groups and (b) differences in information contained in problem-solving tasks that have the same solution requirements.

Since the time that Piaget first used the term "decalage," a substantial amount of developmental research has been stimulated by the adoption of cognitive- or conceptual-change positions that focus on the emergence and development

of processes and operations that evaluate task information. These evaluation processes have been described in various ways, e.g., as attitudes, concepts, rule and transformational structures, and decision strategies. Although Piaget's theory has been the most widely adopted of the cognitive-change positions, the decalage relation is not found exclusively in Piagetian research. It also exists in research motivated by other cognitive-change positions.

Cognitive-change research is concerned with the general area of human problem solving. In studies exploring the development of problem solving, the subject is typically given a task with alternative response choices. These consist of one alternative that is relevant to solving the problem and one or more alternatives that are irrelevant to solution. The solution-relevant alternative is predetermined by an adult experimenter who considers its increasingly reliable choice to be a reflection of problem-solving processes. In this research, it is common to find differences in the performance of subjects at different age levels, with older subjects usually solving problems more accurately and more rapidly than younger ones. The accounts of such differences are typically in terms of qualitative and/or quantitative changes in cognitive structures that, in general, may be characterized as processes that evaluate task information. Two such commonly proposed constructs are (a) structures of logical thought (e.g., Piaget & Inhelder, 1969) and (b) attentional and verbal mediators (e.g., Hagen & Hale, 1973; Kendler & Kendler, 1962). For the Piagetians, development is assumed to proceed with the emergence of qualitatively different and more adult-like structures that are described by models of logic. For the mediationalists, what is assumed to cause age-related differences in problem solving is the development of cognitive, mediational processes that

determine evaluation and selection of information that is relevant to problem solution by either attending to relevant and ignoring irrelevant information (e.g., Hagen & Hale, 1973) or transforming and organizing information into dimensions or concepts (e.g., Kendler & Kendler, 1962).

Because cognitive-change positions contain no clear or distinct theoretical role for perceptual development, there appears to be an implicit assumption that all information in a problem-solving task is perceived identically at all developmental levels. Consequently, age-related performance differences are considered to result from different cognitive structures that evaluate the same information.

But in the case of the conservation decalage, what of the different information in each task that specifies the type of quantity to be conserved? If such differences were assumed to be unimportant because the perception of information across development is considered invariant, then the particular task used to assess the presence of structures relevant to conservation should not matter. However, it can be seen from the conservation decalage that ignoring differences in task information can result in age-related performance differences that are difficult to explain using a cognitive-change position. For example, if 8 year-olds were given a task involving mass while 10-year-olds were given one involving volume, the conclusions drawn from the results would be that younger children, who were able to conserve mass, demonstrated greater cognitive competence than the older children, who were unable to conserve volume.

Within the decalage there are two component relations that have implication for accounts of development. The first is between the characteristics of information in tasks with the same solution requirements and the performance

of subjects from the same developmental level. The second relation is between performance of subjects from one developmental level and that of subjects from other developmental levels in tasks that have the same solution requirements but that may or may not differ in task characteristics.

An instance of the first component relation is seen in the performance of 7-year-olds who solve problems involving mass conservation but fail problems involving weight or volume conservation. The second component relation has implications for the issues being raised when no difference exists between the performance of younger and older subjects or when the younger subjects' performance is more accurate than that of the older subjects. An example is the accuracy of 8-year-olds in a mass problem compared to that of 10-year-olds in a volume problem. Because of the widespread acceptance of cognitive-change positions, the second component relation is rarely expected, and when it occurs, is likely to be viewed as anomalous or unimportant.

In contrast to the way these component decalage relations have been treated in cognitive-change positions, they are of central importance in the perceptual-change position that will now be presented. In this position, such relations are assumed to be a source of information about developmental changes in the perceptual system and how that system determines what information is processed by cognitive structures. Certain of the Gibsons' ideas about perception have been adopted as basic assumptions. These are (a) that relations serve as basic information for the perceptual system, (b) that they are present in the external environment and are not mediated products of cognitive structures, images, stored associations, or inferences, and (c) that they are discovered in increasing numbers by the perceptual system as development proceeds.

We have extended these ideas by proposing that the perceptual system becomes differentially sensitive to information once it has been detected. Changes in sensitivity are assumed to be primarily a function of perceptual experience per se and/or particular environmental contexts and events. With development, perceptual experience increases and perceptual sensitivity to certain relations and categories would therefore be expected to increase. Furthermore, it is proposed that the degree of sensitivity to relations or categories determines how they are perceptually organized and the order in which they are cognitively evaluated for problem solution. That is, the greater the perceptual sensitivity to given information, the higher the probability of its being cognitively evaluated, regardless of the information's appropriateness for problem solution. It would therefore be expected that with increasing development an increasing amount of both relevant and irrelevant information would be cognitively evaluated and either accepted or rejected for problem solution.

With this point of view, we have been assessing, and have found, age-related differences in the relative sensitivity of the perceptual system to common relations, categories, and dimensions. This has been done with traditional salience tasks in which subjects match items that are alike in values representing particular categories but different in values from other categories. In these tasks there is no problem to solve, and therefore no solution-relevant choices. Several choice alternatives are provided, and no evaluative feedback is given. A rank ordered hierarcy of salience scores associated with the frequency of matching certain categories is obtained for each child. From this approach, salience is viewed as a perceptual characteristic of information, and the salience hierarchy is seen as a product of the perceptual system's detection of, experience with, and organization of information.

The following are two of several studies we have carried out to explore the developmental roles of perceptual and cognitive processes. Each yields a demonstration of decalage relations that are often found in much of the literature motivated by cognitive-change positions.

The first of these was designed to assess the effects of perceptual salience on performance in matrix problems like the one shown in Figure 1 of your handout. According to Piagetian theory, what is required for solving any conservation task, as well as other concrete-operational tasks, is the use of cognitive operations that coordinate information from at least two different sources. Inhelder and Piaget (1964) have claimed that the most direct way of assessing the development of such competence is through the use of the matrix task.

A series of nine different matrices was presented to 4- and 6-year-old children. Approximately 3 weeks prior to presenting the matrix tasks, the salience of form, color, and position was assessed, and an ABC hierarchy with A the most and C the least salient dimension was obtained for each child. Half the children from each age group were assigned to an AB condition and received problems composed of values from their A and B dimensions. The remaining half were assigned to an AC condition and received matrices composed of values from their A and C dimensions.

The goal in each problem was to select that compound stimulus from a set of four alternatives that appropriately filled an empty cell in the matrix. The correct card--e.g., number 3 in Figure 1--contained both of the dimensional values appropriate to the empty cell in the matrix. Two of the other cards--numbers 1 and 4 in Figure 1--contained one dimensional value appropriate to the empty cell and one value that was inappropriate.

Both values of the fourth card were inappropriate and did not appear in the matrix.

The results showed that the salience of the relevant dimensions affected matrix solution. More accurate performance was associated with the AB than the AC matrices for both age groups. The younger children failed to solve an average of 4.20 and 5.10 matrices in the AB and AC conditions, respectively, while the older children failed an average of 1.55 and 3.50 matrices in the two respective conditions. These findings represent a case of the first component relation of the decalage and can be accounted for in terms of the salience characteristics of the relevant information.

Even though each matrix problem required a different choice card for solution, for a given child the relevant dimensions were the same for all nine problems. Therefore, the effects of an increase in the perceptual sensitivity to and subsequent evaluation of the relevant dimensions are probably reflected in the decreasing number of errors made on successive problems by the age groups in both conditions. On the last three matrices, the performance of the 4-year-olds in the AB and the 6-year-olds in the AC condition was comparable (mean errors = .8 and .9, respectively). This finding is an instance of the second component relation contained in the decalage. It indicates that, given certain task information, the 4-year-old children were able to solve the matrix problems as successfully as the older children.

The greater overall accuracy of the older subjects may reflect more mature evaluation processes, but how that greater cognitive maturity should be characterized is not clear. From a perceptual-change account it could be reasoned that the older subjects' greater accuracy was due not to greater cognitive maturity but to both of the relevant categories in each problem being more absolutely salient than they were for the younger subjects. Although there was no preassessment measure of absolute salience, its effects were demonstrated in the performance of both age groups. The greater accuracy on AB than on AC matrices indicates that the B dimension was absolutely more salient than the C dimension, even though both were relatively less salient than A in each of the problems.

In another study, we explored the role of perceptual salience in tasks designed to assess selective, attentional processes. In recent years, considerable developmental research on attention has been performed using tasks that afford a comparison between the recall of relevant and incidental information. In a review of this literature by Hagen and Hale (1973), the results of studies involving subjects from 7 to 13 years indicated that although the recall of older subjects was more accurate than that of younger subjects on the initial problem-solving task, a similar amount of incidental recall was usually found for all age groups. That older and younger subjects recalled different amounts of relevant but not incidental information led Hagen and Hale (1973) to conclude that older children are better able than younger children to attend selectively

to relevant information and to ignore that which is incidental to solving a problem. In contrast to the results of these studies, our research--most of which is not presented here--has assessed salience and shown that more incidental as well as relevant information is recalled with increasing age, a finding not easily explained by a selective-attention position.

In the research reviewed by Hagen and Hale the values of the relevant and incidental dimensions were usually separated spatially (e.g., an animal paired with a household object), whereas in our research the relevant and incidental stimulus components were presented as compound stimuli (e.g., two red squares positioned along the top of a card). Focusing on this difference between compound and component stimuli, Hagen and Hale have proposed that when component values of relevant and incidental dimensions are presented as a compound stimulus, it is more efficient for older subjects to process both types of values because considerable effort may need to be expended in distinguishing the components. Such an interpretation, however, results in the problem of determining what kind of performance measure one should use to assess the development of attentional processes. Claiming more mature selection processes for older than younger subjects when the older subjects show less incidental recall and then claiming greater efficiency for older subjects when they show more incidental recall does not seem reasonable.

Because there was no assessment of the salience characteristics of the relevant and incidental categories used in the research reviewed by Hagen and Hale, we assessed salience and used component values to represent the solution-relevant and -irrelevant categories. As in the matrix study, the salience of form, color, and position was assessed about 3 weeks prior to presentation of

the problem-solving task, and an ABC hierarchy was obtained for each of the kindergarten and sixth-grade children who participated. Half of the subjects from each grade level were assigned to Condition AC in which their A dimension was relevant and their C dimension incidental to solving the initial problem. The remaining subjects were assigned to Condition CA and given a problem in which their C dimension was relevant and their A dimension irrelevant to solution.

For this task an array of cards was presented in a tray with six compartments. Figure 2 on your handout is an example of an array. In each compartment were two cards, one containing a value from the relevant dimension (e.g., a black inverted T, representing the form dimension) and the other containing a value from the incidental dimension (e.g., a black bar, centered along the horizontal midline representing the position dimension). The array was repeatedly exposed for brief intervals by raising a lid. Following each exposure, a card containing a relevant dimensional value identical to one in the array was held up, and the subject was asked to indicate the array location of that value on the top of the closed lid. In a second task, the array was never exposed, and the subjects were probed on the location recall of values from the incidental dimension.

The results showed that in the AC and CA conditions of the initial problem the kindergarteners made, respectively, 11.75 and 15.45 errors, while the sixth-graders made 8.19 and 10.44 errors in the two conditions. Both age groups made fewer errors in the recall problem when the more salient dimension was relevant. This is an instance of the first component relation of the decalage. Note also that the total recall accuracy of the younger group in the AC condition approached that of the older group in the CA condition (11.75 vs. 10.44), and that during the last six trials of the task, the younger AC

group had mean errors of 1.81 while the older CA group had mean errors of 2.31. This is an instance of the second component relation of the decalage.

Salience also affected the recall of incidental information. Subjects recalled more when the incidental dimension was high in salience (M errors = 3.47) than when it was low in salience (M errors = 4.72). Furthermore, the sixth-graders recalled more incidental information (M errors = 3.78) than kindergarteners (M errors = 4.41). Only the recall of kindergarteners in the AC condition was found to be at chance level, indicating that they recalled none of the value locations of the C dimension when it was irrelevant to task solution. Interpreting the incidental recall data from a cognitive-change, selective-attention position would lead one to conclude that the older subjects were less successful than the younger subjects in rejecting solution-irrelevant information. The incidental recall data and the decalage associated with the initial problem, however, are both compatible with a perceptual-change position.

Conclusions

In the two example studies just described, instances of the decalage and its component relations have been identified. Although the problem-solving tasks used in this research are associated with particular theoretical traditions and were designed to assess different aspects of psychological development, the obtained decalages have implications for any theory concerned with the development of processes associated with problem solving. In the studies presented here, the characteristic of perceptual salience was identified as a significant determinant of the obtained decalages. In research where salience has not been studied but where decalage components are found, it is reasonable to assume that salience or some other perceptual characteristic of the task information could have played an important role in producing those components.

With further research on the role of salience and other characteristics of information in problem solving, a perceptual-change position may prove to be a desirable alternative to those that focus on cognitive-change. That is, we may become persuaded that the basic and significant changes that occur in psychological development are primarily or exclusively based on the perceptual system's changing sensitivity to relations in the environment rather than on changes in cognitive processes that evaluate those relations. Although at present it cannot be said with much certainty which alternative account will prove more adequate, existing research clearly indicates that a perceptual-change account should at least be viewed as an important extension of a general cognitive-change position. It is also clear that if we are to understand the development of the structure and function of cognitive processes that evaluate and transform task information, we must also understand the perceptual nature of that information and how it changes with development.

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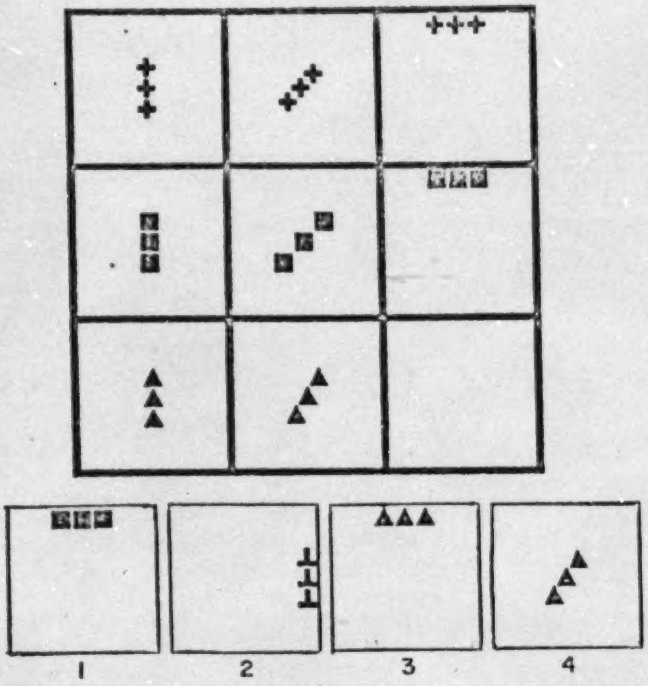

Figure 1. An example matrix and choice cards.

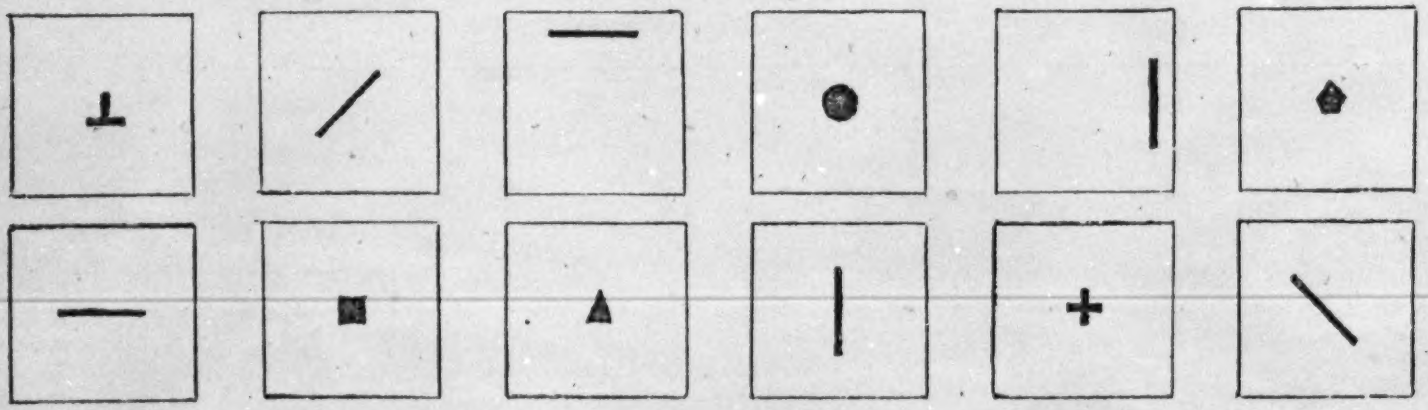

Figure 2. Example of a stimulus array with spatially separated component values of the form and position dimensions.